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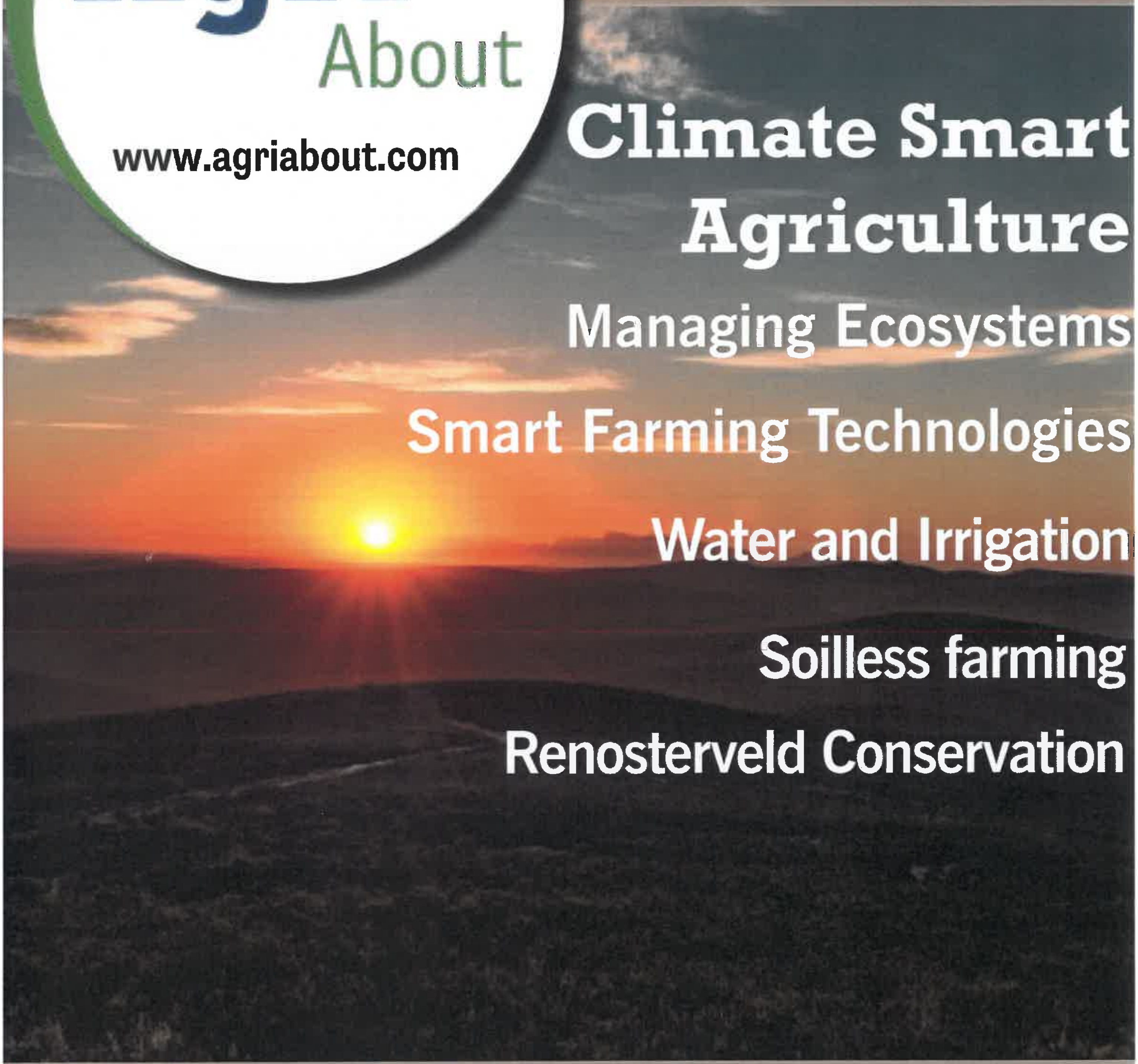

Climate Smart Agriculture

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Partnering with soil microorganisms to improve soil fertility

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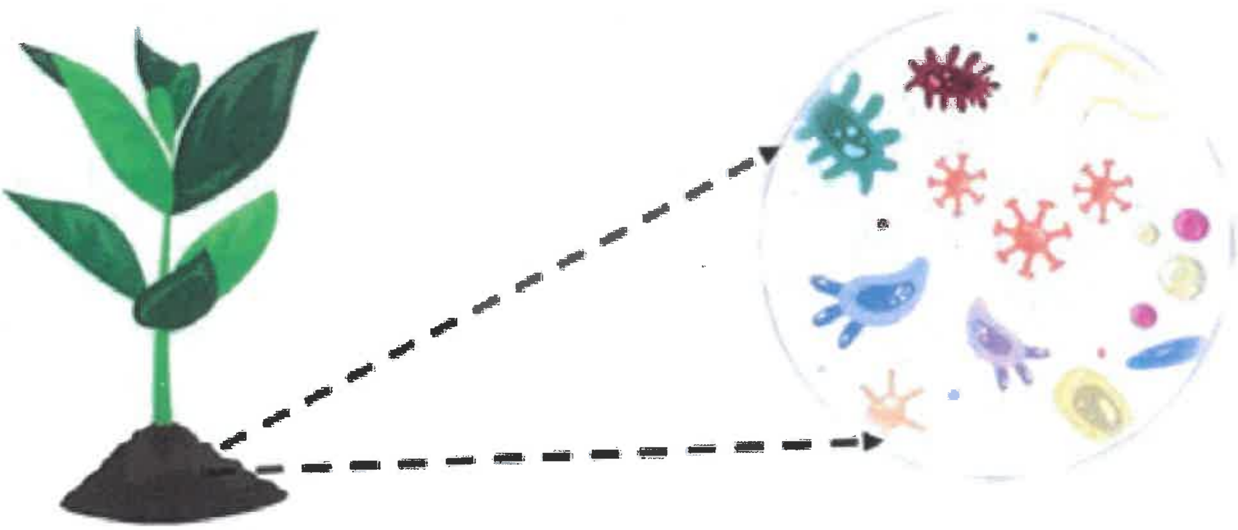
Soil quality and productivity is dependent on many different environmental conditions such as pH, temperature, oxygen, moisture, and nutrient availability. All these factors must be conducive not only for plant growth, but also for soil microbial communities to thrive. Soils are home to billions of bacterial cells, many of which are found in the rhizosphere which is the section of the topsoil that closely interacts with the plant roots and their microorganisms. The interaction between the plant and rhizospheric microbes enables nutrient transfer between the plant and the soil, and in so doing facilitates plant growth.

The **rhizospheric microbiome** comprises bacteria, fungi, protozoa, and archaea that are essential in biogeochemical cycling processes. These processes include conversion and transfer of various nutrients between the soil and the plant, along with many more regulatory processes that remove an array of natural and synthetic pollutants from the



soil. Generally, microbes break down and convert organic compounds into inorganic compounds by the process commonly referred to as mineralization. However, different microorganisms in the rhizosphere are responsible for different energy and nutrient transfer processes to ensure optimal growth and health of the plant.

Bacteria play an important role in the breakdown of organic and inorganic compounds that contain macronutrients, such as nitrogen (N), into forms that are easily accessible by plants. Bacteria are crucial microorganisms that aid in soil formation and structure as well as nutrient and water cycling by decomposing organic matter in the soil. Because they produce different enzymes, they are easily affected by the concentrations of hydrogen ions in the rhizosphere and therefore become highly sensitive to pH. Generally, bacteria constitute most of the plant growth promoting microbiome in the soil and are known as plant growth promoting bacteria.

Fungi are highly adaptable microorganisms that always find a way to thrive even under unfavourable pH and temperature conditions. These microbes are important for decomposition due to their ability to break down different types of organic matter and actively regulate soil carbon (C) and nutrients. Fungi are also biological controllers, contributing to the regulation of soil and plant pests and diseases.

Protozoa are single-celled heterotrophic animals that regulate bacterial populations and balance soil microbial ecology. Protozoa have low N levels and when they ingest bacteria with higher N contents by the process of phagocytosis, they release unused leftover N to plants. Since protozoa specialize in mineralization they mostly occur in the rhizosphere.

Archaea refers to a group of microorganisms that look like bacteria but have significantly different molecular traits. They can be associated with plant growth promotion and nutrient supply. They also could protect plants against environmental stresses as well as participate in the C and N cycles.

Evidently, the rhizospheric microbiome is important for diverse functions that benefit and promote plant growth through utilizing, breaking down and providing nutrients to plants. A poorly maintained rhizosphere can allow pathogenic and non-beneficial soil microorganisms to thrive. Plants need nutrients to grow and reproduce. Other than water, C and N mentioned above, plants also need phosphorus (P), potassium (K), sulphur (S), calcium (Ca), magnesium (Mg), boron (B), chlorine (Cl), copper (Cu), iron (Fe), manganese (Mn), molybdenum (Mo), nickel (Ni) and zinc (Zn) to enable fundamental plant functions (see Table 1).

Conclusion

For better plant growth, it is recommended to not only consider the physical, but also the chemical and biological soil properties. The balance between the chemical and physical characteristics of soil directly affects overall crop production as well as the quality of the harvestable portion. Harmonious interaction between these communities creates a favourable environment for the rhizosphere ecology, thus benefiting the plants. The Agricultural Research Council (ARC) has a proud history of conducting research on soil nutrients and microorganisms. The ARC provides different soil analytical services to farmers, gardeners, and researchers, including brand new tests focussing on soil health. Recommendations and suggestions for soil treatments are also available on request.

For more information on soil analytical services provided by the ARC, visit their website: www.arc.agric.za or e-mail: YourSoil@arc.agric.za

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Table 1: Important nutrients for plant growth

Nutrient	Form of availability to plant	Function	Deficiency symptoms
Carbon	CO_2, HCO_3^-	Maintenance of plant structure Photosynthesis	Limited and slow growth
Nitrogen	NO_3^-, NH_4^+	Protein production Enzymatic reactions Chlorophyll	Pale green or yellow colour in leaves
Phosphorus	$H_2PO_4^-$, HPO_4^{2-}, PO_4^{3-}	Storage and transfer of energy RNA and DNA structure Root, seed, and fruit development Crop quality	Slow and weak growth Poor or slow plant, seed, and fruit development
Potassium	K^+	Enzyme activation Metabolism promotion Water regulation Disease resistance	Chlorosis Lodging and weak stems Low seed and fruit quality
Sulphur	SO_4^{2-}	Forms part of plant protoplasts and production of enzymes	Leaves become yellow-green or yellow
Calcium	Ca^{2+}	Cell structure, elongation, and division	Inhibited growth in younger leaves Appearance of brown chlorotic spots on leaf margins
Magnesium	Mg^{2+}	Formation and production of chlorophyll	Chlorosis in older leaves Yellow-green or white colour between the veins of leaves
Boron	H_2BO_3, $H_2BO_3^-$, HBO_3^{2-}	Growth regulation Cellular development Translocation of sugars	Deformed plant tips
Chlorine	Cl^-	Essential for photosynthesis	Wilting, leaf margins curling, bronzing, chlorosis, and necrosis of leaves
Copper	Cu^{2+}	Activation of enzymes and plant cytochromes	Wilting leaf tips Bluish-green colour Poor growth, delayed flowering, and plant sterility
Iron	Fe^{2+}	Synthesis of chlorophyll Metabolic processes Activation of enzymes	Chlorosis on younger leaves
Manganese	Mn^{2+}	Activation of enzymes Hill reaction of photosystem II	Chlorosis (yellowing) on young leaves Tan, sunken spots between leaf veins
Molybdenum	MoO_4^{2-}	Enable plants to utilize N	Yellow-green to yellow leaves
Nickel	Ni^{2+}	Iron metabolism	Necrosis of leaf tips Chlorosis of young leaves Reduced leaf size Curled leaf growth
Zinc	Zn^{2+}	Activation of enzymes Breakdown of protein	Yellowing of leaves Chlorosis in base of leaf near to stem